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# Changes in Some Chemical Properties of Arid Soils as Affected by Synthetic Polymers

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*Four soil conditioners, Broadleaf P4, Agrihope, Aquasorb, and Hydrogel, were used in a laboratory study to investigate the effect of these polymers on chemical properties of two calcareous sand and loam soils. Four concentrations of each polymer used were 0.0%, 0.2%, 0.4%, and 0.6% (w/w). All treatments were irrigated weekly to 60% water holding capacity for a total of 16 wetting and drying cycles. The addition of conditioners induced a substantial change in the selected soil chemical properties. For both soils, pH and EC values increased significantly with corresponding increase in concentrations of all conditioners. The extractable nutrients (Zn, Cu, Mn, Fe, P, and K) fluctuated irregularly with the four concentrations of each conditioner. In sandy soil the application of all conditioners significantly increased extractable P, whereas extractable Zn remained unaffected. Extractable Mn significantly decreased with Broadleaf and Aquasorb application but increased with Agrihope. Extractable Fe increased with Broadleaf and Hydrogel. In loamy soil the extractable Zn, Mn, and P were not affected by the applied conditioners. Extractable Fe decreased by Broadleaf application, but significantly increased with Aquasorb addition. Extractable Cu decreased only at the highest concentration of Broadleaf conditioner. Extractable K significantly increased with Hydrogel. The results obtained confirm our previous conclusions that application of synthetic conditioners may have deleterious effects on some chemical properties of arid calcareous soils.*

**Keywords** arid soils, electrical conductivity, micronutrients, phosphorus, potassium, soil reaction, synthetic polymers

Many studies have been conducted using synthetic soil conditioners to improve physical properties of coarse-textured soils in arid and semiarid regions, such as Saudi Arabia. The improved properties included better aggregation of soil particles as well as improved water-use efficiency (Wang & Boogher, 1987) and reduced infiltration rate (Mustafa et al., 1988), increased water holding capacity (Al-Omran et al., 1987; Choudhary et al., 1995), and decreased evaporation losses (Choudhary et al., 1995). However, few investigations have been undertaken to define the effects of synthetic soil conditioners on chemical properties of coarse textured soils, particularly under local conditions. Previous studies by the authors have illustrated that synthetic soil conditioners caused a significant increase in soil pH and EC, and decrease in extractable nutrients (Falatah & Al-Mustafa, 1993; Falatah & Al-Omran, 1995).

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El-Hady et al. (1990) studied the effect of polyacrylamide (PAM) as a conditioner on extractable nutrients of sandy soil. They found that the extractability of nutrients differs with the conditioner application rates and the method of application. In a pot study, Sabrah et al. (1993) added three different conditioners to sandy soil collected from an intensively cultivated area. They found that changes in pH and EC were related to the type of soil conditioner used. These limited studies suggested that further investigation was needed to evaluate the effect of different type of conditioners on soil chemical properties. Hence the main aim of this study was to investigate the effects of four newly marketed synthetic commercial conditioners on selected chemical properties and nutrient extractability of two calcareous soils.

## Materials and Methods

Two composite surface (0–30 cm) calcareous soil samples from a sand (Typic Torripsamments) and a loam (Typic Torriorthents) were used in this study. The samples were collected from the College of Agriculture Experimental and Research Farm located at Dierab, Saudi Arabia. The composite soil samples were air dried and passed through a 2-mm sieve. Selected soil properties were determined by standard procedures. Particle size analysis was carried out by the hydrometer method (Day, 1965). Soil organic matter (O.M.) was determined by the Walkley and Black procedure (Jackson, 1967), and calcium carbonate by calcimeter (Allision & Moodie, 1965). Soil pH was measured in saturated paste using deionized water and electrical conductivity ($EC_e$) in saturated extract. P, K, and micronutrients were extracted with ammonium bicarbonate diethylenetriaminepenta acetic acid (AB-DTPA) solution according to the method of Soltanpour and Schwab (1977). The extractable Zn, Cu, Mn, and Fe were determined by atomic absorption spectrophotometry, and K was determined by flame photometry. The synthetic conditioners used were Broadleaf P4, Agrihope, Aquasorb, and Hydrogel. (The registered trade names of polymers used does not constitute an official endorsement of the products.) The first three conditioners are hydrophilic, high-molecular-weight, cross-linked, Na-based polyacrylamides, whereas the fourth, Hydrogel, is a K-acrylate-starch copolymer. Commercial sources and other properties of these polymers are reported in detail elsewhere (Choudhary et al., 1995). The treatments consisted of four concentrations, namely, 0.0%, 0.2%, 0.4%, and 0.6% by weight, of each conditioner added to the soils. The added conditioners were thoroughly hand mixed with bulk soils (2 kg) to ensure uniform mixing. Subsamples weighing 500 g were taken from each treatment and placed in plastic containers (11 × 11 × 8 cm). The required amount of deionized water was added, and soil moisture was maintained at 60% water holding capacity (WHC) by weighing weekly throughout the study. Each treatment was replicated three times. The containers were kept at 21°C and subjected to 16 wetting and drying cycles to simulate a growing season. The results reported are the average of two determinations per replicate. The data were analyzed using SASS ANOVA (SAS Institute, 1982).

## Results and Discussion

Selected physical and chemical properties of both soils are given in Table 1.

### *Soil Reaction (pH)*

The changes in the pH values of conditioner-treated soil samples compared with untreated samples (0.0%) are shown in Figure 1. Soil pH significantly ($p < 0.05$) increased with

Table 1

Some physical and chemical properties of studied soils.

| | Sand | Loam |
|---|---|---|
| Particle size distribution (%) | | |
| Sand | 90 | 43 |
| Silt | 4 | 38 |
| Clay | 6 | 19 |
| pH | 8.08 | 7.91 |
| $EC_e$(dS $m^{-1}$) | 0.43 | 0.59 |
| $CaCO_3$ (%) | 27.90 | 36.50 |
| O.M. (%) | 0.12 | 0.25 |
| AB-DTPA extractable nutrients (mg $kg^{-1}$) | | |
| Zn | 2.44 | 0.47 |
| Cu | 0.41 | 0.87 |
| Mn | 2.95 | 3.93 |
| Fe | 2.48 | 1.47 |
| P | 31.83 | 29.83 |
| K | 79.33 | 291.00 |

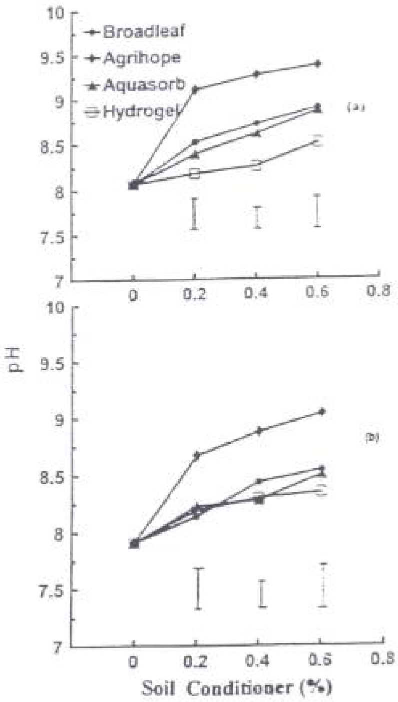
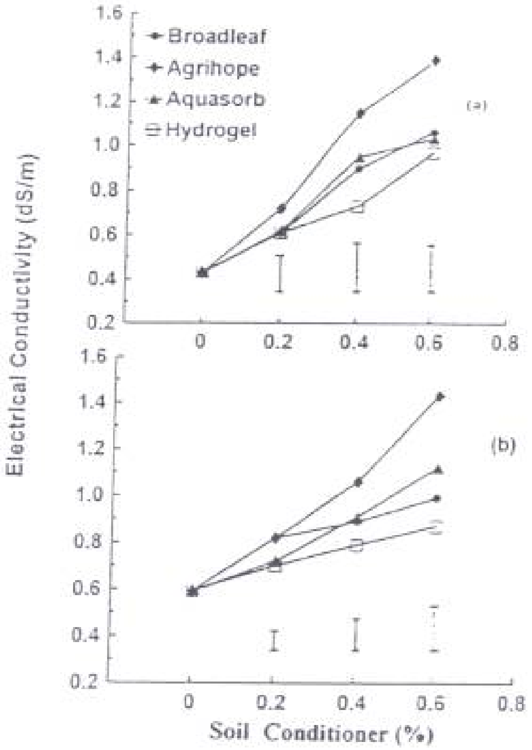



**Figure 1.** The pH of (a) sand soil and (b) loam soil as affected by various concentrations of gel-forming conditioners.




ical conductivity of (a) sand soil and (b) loam soil as affected by various concen- orming conditioners.

centrations of all four conditioners relative to controls. The increase in soil tioner application reflects both the high pH of the conditioners used and nsumption of protons during the reduction process occurring in the treated al., 1985). The relationship between the conditioners and soil pH values unning regression analysis, and the results showed that correlation coef- ween soil pH and Broadleaf P4, Agrihope, Aquasorb, and Hydrogel were 998, and 0.941 for the sand and 0.986, 0.924, 0.968, and 0.941 for the loam ly. A similar trend was reported previously by Falatah and Al-Mustafa tah and Al-Omran (1995) while working with Jalma-Gel conditioner. The values of soils with increase in conditioner concentrations ranked as pe > Broadleaf ≥ Aquasorb > Hydrogel.

*Conductivity*

onductivity of the conditioner-treated soils was significantly greater than ective controls (Figure 2). This could be due to the salt content of the oreover, the soils were incubated for 16 weekly wetting and drying cycles isture regime (60%, WHC), resulting in dissociation of $Ca^{2+}$ from $CaCO_3$ asing the total electrolyte concentrations of the soils. This trend was more gher conditioner concentrations. However, the increase in soil EC with addition of synthetic conditioners is consistent with previous reports (Falatah & Al-Omran, 1995).

### *Micronutrients (Zn, Cu, Mn, Fe)*

Changes in extractable micronutrients due to synthetic conditioner application to both soils in relation to controls are presented in Tables 2 and 3. No significant differences ($p < 0.05$) were found in extractable Zn between treated and untreated samples of both soils. Extractable Cu of the loam soil decreased with increasing addition of Broadleaf conditioner, and this decrease was more significant ($p < 0.05$) at the highest rate (0.6%). For the sand soil, extractable Cu was significantly decreased with increasing rate of Hydrogel conditioner, the reduction being about 41%, 39%, and 37% for samples treated with 0.2%, 0.4%, and 0.6%, respectively. The decrease in extractable Cu was correlated ($r = -0.740$) with increase in soil pH associated with Hydrogel addition (Table 2).

**Table 2**
Effect of concentrations and types of gel-forming conditioners on Zn, Cu, Mn, and Fe contents (mg $kg^{-1}$) of sand soil

| Conditioner concentration (%) | Broadleaf | Agrihope | Aquasorb | Hydrogel | $LSD_{0.05}$ |
|---|---|---|---|---|---|
| | | Zn | | | |
| 0.0 | 2.44 | 2.44 | 2.44 | 2.44 | NS |
| 0.2 | 3.09 | 2.71 | 2.38 | 2.74 | 0.45 |
| 0.4 | 2.58 | 2.70 | 2.65 | 2.64 | NS |
| 0.6 | 2.70 | 2.91 | 2.57 | 2.89 | NS |
| $LSD_{0.05}$ | NS | NS | NS | NS | |
| | | Cu | | | |
| 0.0 | 0.41 | 0.41 | 0.41 | 0.41 | NS |
| 0.2 | 0.35 | 0.21 | 0.25 | 0.24 | NS |
| 0.4 | 0.43 | 0.27 | 0.23 | 0.25 | 0.06 |
| 0.6 | 0.27 | .33 | 0.34 | 0.26 | NS |
| $LSD_{0.05}$ | NS | NS | NS | 0.13 | |
| | | Mn | | | |
| 0.0 | 2.95 | 2.95 | 2.95 | 2.95 | NS |
| 0.2 | 2.87 | 3.04 | 2.92 | 2.75 | NS |
| 0.4 | 2.88 | 3.02 | 2.74 | 2.81 | NS |
| 0.6 | 2.74 | 3.18 | 2.49 | 2.76 | NS |
| $LSD_{0.05}$ | 0.14 | 0.14 | 0.32 | NS | |
| | | Fe | | | |
| 0.0 | 2.48 | 2.48 | 2.48 | 2.48 | NS |
| 0.2 | 2.62 | 2.42 | 2.76 | 2.70 | NS |
| 0.4 | 2.89 | 2.27 | 2.65 | 2.68 | NS |
| 0.6 | 2.74 | 2.39 | 2.49 | 2.97 | NS |
| $LSD_{0.05}$ | 0.31 | NS | NS | NS | |

$LSD_{0.05}$, least significant difference at $p = 0.05$; NS, not significant.

Effect of concentrations and types of gel-forming conditioners on Zn, Cu, Mn, and Fe contents (mg $kg^{-1}$) of loam soil

| Conditioner concentration (%) | Broadleaf | Agrihope | Aquasorb | Hydrogel | $LSD_{0.05}$ |
|---|---|---|---|---|---|
| | | Zn | | | |
| 0.0 | 0.47 | 0.47 | 0.47 | 0.47 | NS |
| 0.2 | 0.42 | 0.41 | 0.37 | 0.41 | NS |
| 0.4 | 0.41 | 0.43 | 0.38 | 0.43 | NS |
| 0.6 | 0.45 | 0.41 | 0.43 | 0.44 | NS |
| $LSD_{0.05}$ | NS | NS | NS | NS | |
| | | Cu | | | |
| 0.0 | 0.87 | 0.87 | 0.87 | 0.87 | NS |
| 0.2 | 0.91 | 0.91 | 0.87 | 1.06 | NS |
| 0.4 | 0.88 | 0.84 | 0.99 | 0.99 | NS |
| 0.6 | 0.83 | 0.85 | 1.08 | 0.98 | NS |
| $LSD_{0.05}$ | 0.07 | NS | NS | NS | |
| | | Mn | | | |
| 0.0 | 3.93 | 3.93 | 3.93 | 3.93 | NS |
| 0.2 | 3.81 | 3.87 | 3.89 | 3.95 | NS |
| 0.4 | 3.83 | 3.77 | 3.91 | 3.99 | NS |
| 0.6 | 3.83 | 3.94 | 3.89 | 3.93 | NS |
| $LSD_{0.05}$ | 0.07 | NS | NS | NS | |
| | | Mn | | | |
| 0.0 | 3.93 | 3.93 | 3.93 | 3.93 | NS |
| 0.2 | 3.81 | 3.87 | 3.89 | 3.95 | NS |
| 0.4 | 3.83 | 3.77 | 3.91 | 3.99 | NS |
| 0.6 | 3.83 | 3.94 | 3.89 | 3.93 | NS |
| $LSD_{0.05}$ | NS | NS | NS | NS | |
| | | Fe | | | |
| 0.0 | 1.47 | 1.47 | 1.47 | 1.47 | NS |
| 0.2 | 1.45 | 1.58 | 1.69 | 1.70 | NS |
| 0.4 | 1.37 | 1.55 | 1.74 | 1.71 | 0.32 |
| 0.6 | 1.29 | 1.63 | 2.02 | 1.65 | 0.22 |
| $LSD_{0.05}$ | 0.11 | NS | 0.27 | NS | |

$LSD_{0.05}$, least significant difference at $p = 0.05$; NS, not significant.

Similar to the results for extractable Zn, addition of conditioners did not cause any significant changes in extractable Mn of the loam soil (Table 3). However, for the sand soil, extractable Mn was significantly decreased with addition of Broadleaf and Aquasorb (Table 2). The reduction in extractable Mn of the sand soil treated with 0.2%, 0.4%, and 0.6% of Aquasorb was 1%, 7%, and 16%, respectively. The respective decrease in extractable Mn caused by the rate of Broadleaf conditioner was about 2%, 3%, and 7%. This decrease was significantly correlated to the increase in soil pH due to Broadleaf and Aquasorb application to this soil with $r = -0.922$ and $-0.955$, respectively. However, extractable Mn of sand soil showed a tendency to increase only with addition of Agrihope conditioner. This increase was significant only at the highest rate (0.6%). Knowing the effect of Agrihope on the pH of the sand soil, one would expect extractable Mn to decrease rather than increase. However, this finding proved that the general concept of a decrease in extractable Mn with increasing soil pH (Lindsay & Norvell, 1969; Shuman, 1975) was not valid in the present study.

Extractable iron of both soils was significantly affected ($p < 0.05$) by the Broadleaf and Aquasorb treatments (Tables 2 and 3). The addition of Broadleaf considerably decreased extractable Fe of the loam soil, but significantly increased extractable Fe of the sand soil when compared with the control.

### *Macronutrients (P and K)*

The change in extractable P due to the addition of conditioners to both soils is presented in Table 4. Statistical analysis of extractable P from the loam soil treated with all four conditioners indicated no significant ($p < 0.05$) effect on extractable P compared with the control. This is similar to the extractable Zn and Mn response to the conditioner appli-

**Table 4**

Effect of concentrations and types of gel-forming conditioners on K and P contents (mg $kg^{-1}$) of studied soils

| Conditioner concentration (%) | Broadleaf | Agrihope | Aquasorb | Hydrogel | $LSD_{0.05}$ |
|---|---|---|---|---|---|
| | | K in Sand | | | |
| 0.0 | 79.3 | 79.3 | 79.3 | 79.3 | NS |
| 0.2 | 74.3 | 71.0 | 69.0 | 267.0 | 16.5 |
| 0.4 | 70.0 | 63.0 | 72.0 | 453.3 | 65.8 |
| 0.6 | 72.0 | 76.0 | 71.6 | 700.0 | 12.3 |
| $LSD_{0.05}$ | 3.5 | 4.4 | 4.1 | 67.1 | |
| | | P in Sand | | | |
| 0.0 | 31.8 | 31.8 | 31.8 | 31.8 | NS |
| 0.2 | 36.8 | 38.0 | 39.6 | 43.17 | NS |
| 0.4 | 42.3 | 42.5 | 39.8 | 44.5 | NS |
| 0.6 | 41.6 | 42.8 | 45.3 | 40.8 | NS |
| $LSD_{0.05}$ | 4.2 | 6.9 | 5.8 | 3.4 | |
| | | K in Loam | | | |
| 0.0 | 291 | 291 | 291 | 291 | NS |
| 0.2 | 288 | 287 | 293 | 502 | 23.0 |
| 0.4 | 283 | 284 | 294 | 688 | 15.3 |
| 0.6 | 286 | 289 | 300 | 898 | 32.5 |
| $LSD_{0.05}$ | NS | NS | NS | 35.6 | |
| | | P in Loam | | | |
| 0.0 | 29.8 | 29.8 | 29.8 | 29.8 | NS |
| 0.2 | 31.1 | 27.1 | 29.8 | 29.8 | NS |
| 0.4 | 30.3 | 28.8 | 30.3 | 26.3 | NS |
| 0.6 | 29.5 | 29.1 | 30.3 | 26.3 | NS |
| $LSD_{0.05}$ | NS | NS | NS | NS | |

cation. While in sand soil, extractable P significantly increased with increasing rate of application for all conditioners relative to the control. Extractable P was increased despite the consistent increase in soil pH. This increase could be partially due to the formation of complex of soil P with the added conditioners that retained P in extractable form.

Extractable K from both soils was affected by conditioner type and rate. As a result, the effect of conditioner rates and conditioner types on extractable K is given in Table 4. In general, increasing rates of conditioner application to the sand resulted in a significant decrease in extractable K, except with Hydrogel conditioner, for which extractable K significantly ($p < 0.05$) increased with increasing Hydrogel rates when compared with the control.

For the loam soil, the effect of conditioner rate on extractable K was not significant, except with Hydrogel conditioner, which resulted in a substantial increase of extractable K with increasing levels of Hydrogel. This was basically due to the K-based property of Hydrogel and hence the main source of high K in the extracts.

## Conclusions

The results of this investigation indicated substantial changes in the studied chemical properties of both soils following conditioner addition. The main changes are deteriorative, involving significant increase in pH as well as concurrent increase in EC values. Other results include the inconsistent changes in extractable macronutrients and micronutrients with increasing rates of application for all four conditioners. In general, this reconfirms our previous findings that use of synthetic conditioners results in deleterious effects on some chemical properties of arid calcareous soils.

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